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Pushing the Envelope of Computing in Space

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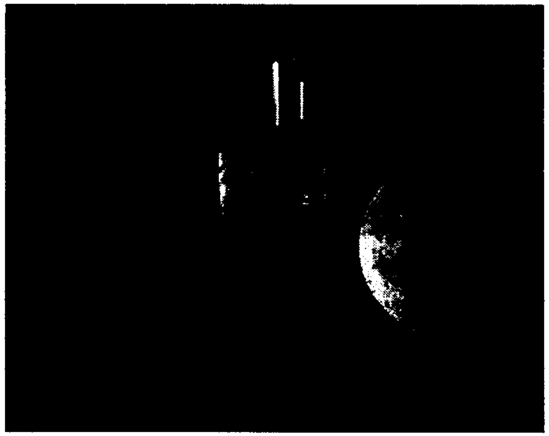
Vision:

Move Earth-based Scalable Supercomputing Technology into Space

New FY96 Start under NASA High Performance Computing Program



REE Goals/Benefits

- Drive the development of low power, scalable, fault tolerant spacecraft computers in partnership with Industry
- Enable a new class of science missions by the availability of high performance spaceborne computing

REE Approach - Partner with Industry and Academia

- Develop and Validate 500 - 1000 Mops/Mflops per watt technologies
- Develop scalable fault tolerant architectures which degrade gracefully
- Demonstrate a new class of onboard applications in partnership with NASA Scientists and Mission Managers

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[illegible]

Applications Drivers

High Data Rate Sensors
- *SAR, Hyperspectral Imagers, Megapixal CCDs*

Autonomous Spacecraft Operations
- *"Fire & Forget" spacecraft, planetary rovers, ...*

In-Situ Knowledge Discovery
- *Feature Extraction, Change Detection, ...*

Downlink Bandwidth Limitations

Technology Drivers

Rad-hard processors 3 - 5 yrs behind COTS
- *and falling farther behind ...*

Design-to-Mission computers too expensive
- *and lead time is too long ...*

Available onboard power declining

Launch vehicle costs driving mass budget

REE Applications/Software Investments

Science Driven Applications Teams
- *Onboard Data Analysis Algorithms*
- *Scientist Authored Onboard Applications*

Real Time, Fault Tolerant OS Development

Autonomous Navigation, Control, and Health Monitoring

REE Technology Thrusts

COTS use in Space
- *SOI processed COTS (COTS+)*
- *Scalable Interconnect Architectures*
- *Software Implemented Fault Tolerance*

Revolutionary Processor Technologies
- *Processor-In-Memory*
- *Reconfigurable Computing*

Low Power Technology Investment
- *1.5 - !.0 Volts or less*

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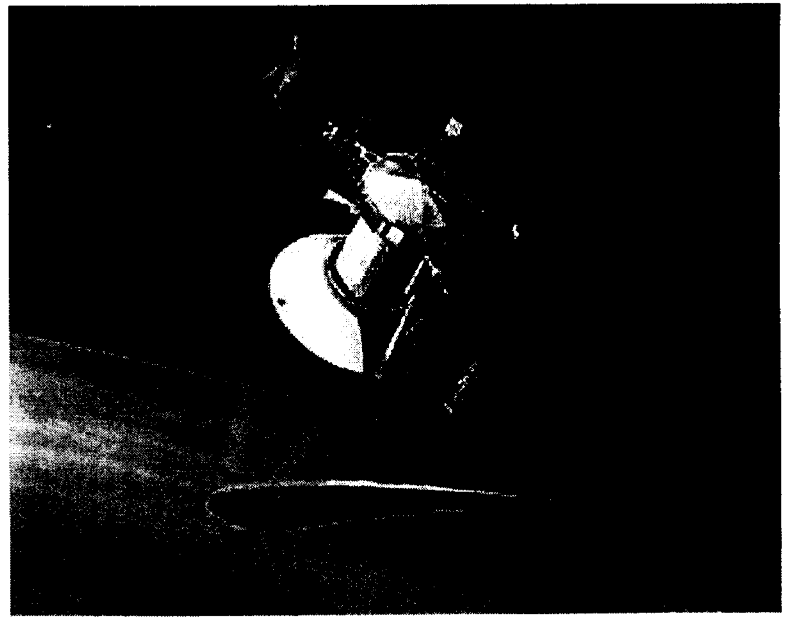
High Data Rate Sensors

- Missions to the inner Solar System, including missions to Planet Earth.
- Missions characterized by high electrical power available, high data rate from instruments, and high computing performance required.
- Mission to monitor climate, oceans, forrests, volcanoes, earthquakes, ozone loss, tsunamis, global warming, etc.
- Possible on-board computing tasks include science analysis, feature extraction, and event triggers.



Scalable spaceborne "supercomputers" will support high data rate instruments such as synthetic aperture radar to learn more about our home world, the Earth.

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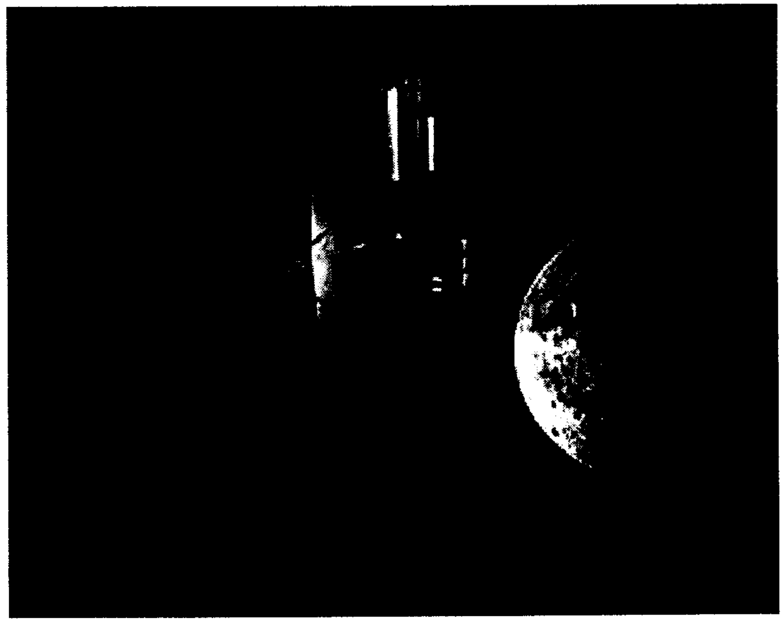
Deep Space Missions

- Missions to the outer Solar System, including missions to the Kuiper Belt.
- Missions characterized by low electrical power available, low bandwidth to the Earth, and high reliability required for missions of long duration.
- Missions to explore of new worlds and investigate the origin of the Solar System.
- Possible on-board computing tasks include navigation and trajectory maintenance, information extraction, and data compression.



Fault-tolerant flight computers will operate on less than a watt of electrical power, enabling low-cost deep-space missions such as Pluto Express.

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Highly Autonomous Robotic Vehicles

- Missions to explore Mars, its surface, atmosphere, and satellites.
- Missions characterized by low electrical power, low bandwidth to the Earth, and harsh day-night temperature extremes.
- Missions to explore of the surfaces of other bodies (e.g., the Moon, Mercury, Io, Titan).
- Possible on-board computing tasks include rover navigation, mineral identification and sample collection, search for water and evidence of life and prepare for human exploration.

Highly-autonomous "smart" microrovers will explore the surface of Mars searching for evidence of ancient life and preparing the way for human exploration.

REE Technical Approach

- Develop breadboard flight computer architectures and system software and demonstrate them in ground testbeds.
- Develop prototypes flight computing systems and validate them in space.
- *Identify and develop scalable spaceborne applications and demonstrate first in ground testbeds and then in flight.*

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The Challenge Applications Teams

We are looking for a New Class of Spaceborne Applications:

- High Data Rate Instruments - in situ analysis
- Highly Autonomous Capabilities
- Complex analysis with knowledge return
- Power constrained science investigations
- ??

We want a variety of Science and Autonomy Applications from throughout the Earth and Space Science Community

And teams of Scientists and Mission planners to Challenge the State of the Art:

- 5 or 6 teams lead by Space or Earth Scientists, or Mission Ops, preferably with missions already proposed or conceived
- Assume 100x more computing capability than is available today
- Same downlink bandwidths/latencies
- What would you do?

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The Challenge Applications Teams

What we need from the teams:

- Applications Prototypes (maybe on a couple of different testbeds)
- Exploration of Application implemented fault detection/ mitigation
- Analysis
  - Compute Operations types, memory requirements, Mops/Flops, OS/ hardware implemented fault tolerance requirements
  - Secondary storage requirements? OS services? Programming Environment?
  - Real Time Requirements?
- Willingness to answer questions and explore new ways of doing things!

We need Them to Become Part of the Project!

What the Project will provide:

- Funding (perhaps $200K/year/team for 2 - 3 years)
- Algorithm or Applications Design help (if desired)
- Testbed Access
- Fault Tolerance or Fault Mitigation Support

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Proposed REE Partnerships

- Phillips Lab - Improved Space Computer Program
  - Rad-hard Scalable Open Architectures
  - COTS + Software Implemented Fault Tolerance
  - Real Time, Fault Tolerant OS
- DOD - Advanced Common Processor Program
  - Software Development Tools/Portability
  - Open Architectures
  - ACP Testbed - NASA Applications Experiments
- DARPA -
  - Programming Tools
  - Reliable Computing (Fault Tolerant OS, Messaging)
  - Processor-In-Memory
  - Reconfigurable Computing (FPGAs)

REE is looking for Joint and Coordinated Investment Opportunities to Maximize Leverage and Avoid Duplications

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Past Year's Activities

Five Study Contract Teams from Industry/Academia Roadmapped Promising Technologies

Developed Potential Onboard Applications Benchmarks

Participated in NASA OSS Technology Roadmapping Activities

STUDY CONTRACT TEAM LEADERS
Team Partners

FY97 Plans

Establish Partnerships with DOD & DARPA

Begin Low Power (PIM) R&D Activities

Solicit and Select REE 1st Generation Prototype Industrial Partners

Establish REE Science Applications Teams, in Partnership with the New Millennium Program

Begin R&D Activities in Software Implemented Fault Tolerance and Autonomy

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Processor-In-Memory - NASA's Interest

- **Power Performance is a key metric**
- **Integrating CPUs into memory has significant power savings**
- **Digital signal processing is a minority of NASA applications**
- **PIM in die stacks could enable autonomous micro-rover missions**

    1 - 2 watt GP computing budget!
- **Potential high risk/high payoff technology insertion into scalable spaceborne architectures (Sea of PIMs ?)**

Proposed PIM Development Strategy

- **2+ generations rapid development demos**

    18 - 20 Months Start to Part

    CPUs in SRAM 1st, then DRAM, multi-threading capability
- **Best process technology with path to rad-hard implementation**

    1st generation in .35 micron
- **Maximum leverage of commercial designs**
- **Scalability features a requirement**

Looking for DARPA partnership on architecture, design (NASA can do fab)

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DARPA Reliable Computing - REE Interest

- **REE will pursue COTS based non rad-hard scalable architectures**
- **Reliability to be dealt with at the system level (hardware+software)**
- **Graceful degradation a key feature**
- **No critical components / No single points of failure**

REE System Software focus - Software Implemented Fault Tolerance

- **Application selectable levels of fault tolerance**
  - *simple restart*
  - *check point/role back*
  - *operate through*
  - *potentially interested in real-time operate-through*
- **Distributed real-time fault tolerant OS**

Potential REE leverage of DARPA investments

- **Extend for reliable MPI ?**
- **Insert into commercial RTOS ?**
- **Expanded SIFT testbed at JPL ?**

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NASA - DARPA MOU in negotiation

JPL Reliable Computing Project already listed

REE proposes additional cooperation on PIM be added

- '97 joint funding of 1st gen scalable PIM demo
- Continued joint funding of 2nd gen scalable PIM architectures, demo

REE would like to be a focus problem for DARPA Reliable Computing Program

- REE Applications, FT requirements used as test problems
- REE testbeds could be host platforms for RC demonstrations
- Potential out-year flight demonstration?

Other Potential Collaborations?